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(54) Structural connections

(57) A structural connection between a tubular thermosetting plastics member (6) and a thermoplastics or aluminium end cap (8) is described. An end of the tubular member is inserted into an annular, axially extending gap (18) in the thermoplastics end cap (8). The inner and outer wall surfaces of the gap (18) are threaded. Adhesive fills the space between the end of the tubular member and the threaded surfaces of the gap.

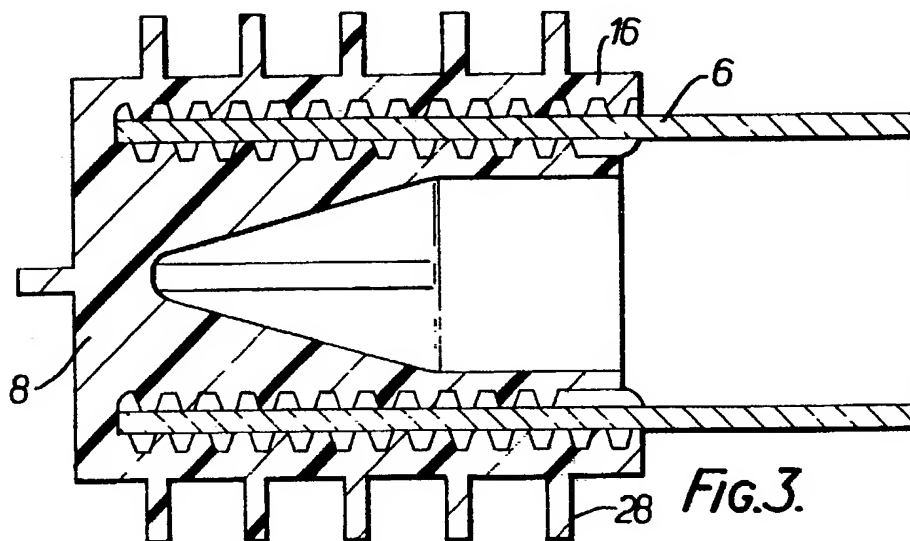
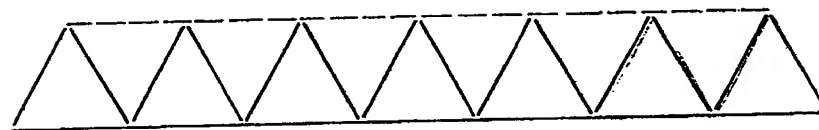
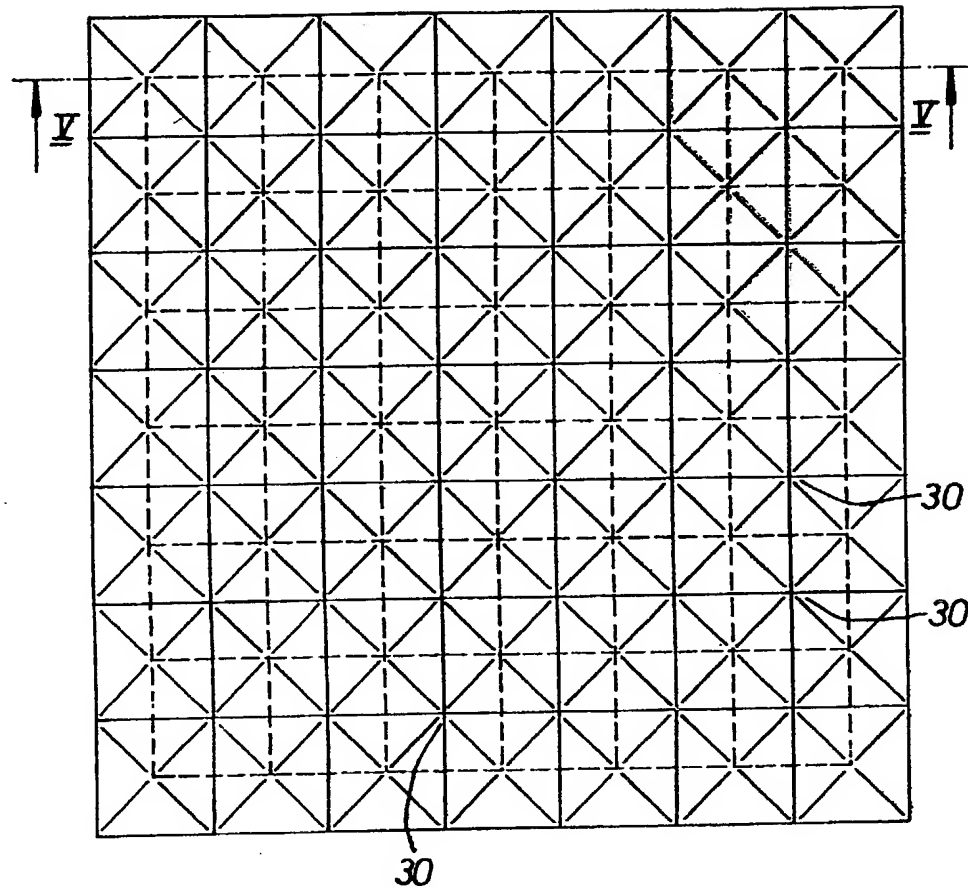


Fig. 3.



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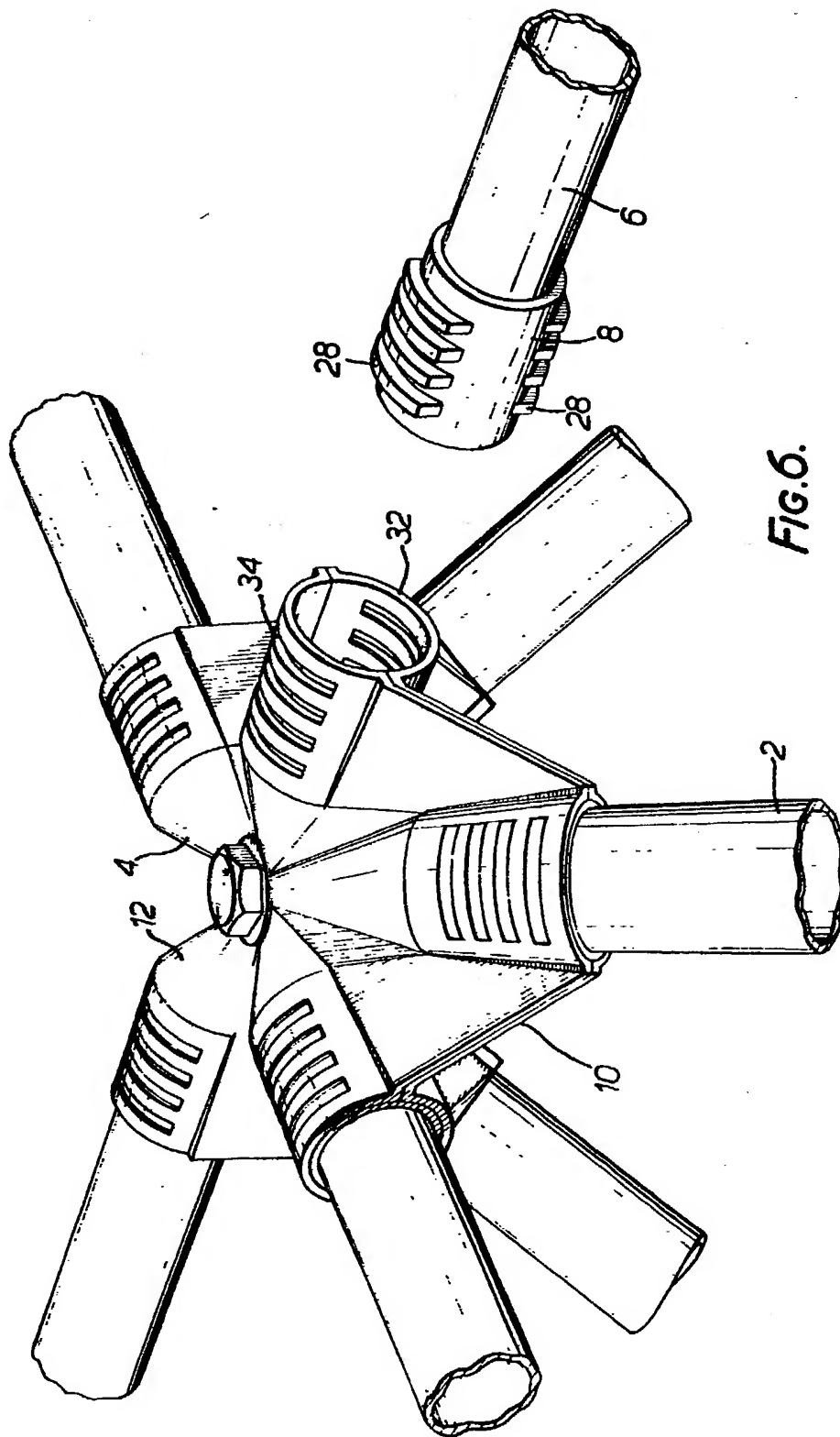


FIG. 6.

## SPECIFICATION

## Structural connections

5 The present invention relates to structural connections between thermo-setting polymer and thermoplastic polymer or aluminium elements, and methods of forming such structural connections.

10 The method of the invention is particularly, but not exclusively, suitable for connecting end caps to polymer tubes to form component members for the construction of structures.

15 Spaceframes are usually built up from simple, prefabricated units (i.e. members and nodes), which are often of standard size and shape. Such units are mass produced in the factory and can easily and rapidly be assembled on site by semi-skilled labour. The small size of the components greatly simplifies handling, transportation and erection.

20 Spaceframe roofs are extremely rigid and stiff, and have an exceptional ability to resist large, concentrated or asymmetrical loading. It has been shown that, even when badly damaged, double layer grids never collapse rapidly; this is of particular importance in the case of fire.

25 Load-bearing spaceframes have conventionally been constructed of steel or aluminium component members and nodes. However, in order to provide a less expensive spaceframe structure particularly suitable for smaller roofing spans of, for example, less than 10 to 15 metres, it would be desirable to use polymer materials.

30 If the manufacturing costs of a lightweight plastics spaceframe are to be low, the structure must make use of injection moulded nodes. Polymers suitable for such injection mouldings would normally be of the thermoplastics variety while those suitable for the tubular members of the spaceframe would be of the thermosetting variety (for example, polyester). There are considerable differences between these two types; for example, thermoplastics are usually weaker and are more difficult to chemically bond than thermosetting polymers.

35 A suitable material for the tubular members would be pultruded G.R.P. (glass reinforced polyester). Tubes of this material have excellent strength and stiffness properties, but it has always been exceptionally difficult to transfer loads from the material. If the tubes are drilled to receive bolted connections, the continuous glass fibres are broken and the material severely weakened; the bolts simply shear through the tubes.

40 It is not possible to weld the material, and the process of threading the tubes again merely breaks the load-carrying glass fibres. The only practical method of utilizing the full strength of the material is to transfer load by adhesive bonding. The main problem with the use of adhesives, however, is the control of the glue line thickness; this is critical if a good bond is to be achieved. If the glue line is too thick then the adhesive will shear through at a low load; if the glue line is too thin, then there is the risk that, in

places, no adhesive exists at all. In addition it is generally considered by the construction industry that adhesives are not suitable outside the controlled conditions of factories.

65 The present invention accordingly provides a structural connection comprising two elements, one of which comprises a first polymer material and the other of which comprises thermoplastics material or aluminium, a recess in one element which accommodates an end portion of the other element, the thermoplastics or aluminium one of each pair of co-operating surfaces of said elements in said recess being provided with a grooved surface, and adhesive substantially filling the space between each pair of co-operating surfaces which adhesive chemically bonds to the first polymer material.

70 The invention also includes a method of forming a structural connection between an end of a cylindrical member and a closed-ended member having an internally threaded annular wall defining a recess having substantially the same diameter as the cylindrical member comprising the steps of introducing adhesive into said recess and pushing said cylindrical member into the recess until it reaches the closed end, thereby forcing adhesive to run around the thread to substantially completely fill the space between the wall and the cylindrical member.

75 An embodiment of the invention will now be described, by way of example only, with reference to the accompanying diagrammatic drawings, in which:-  
Figure 1 is a side view of an end of a tubular member for use in spaceframe construction;

80 Figure 2 shows a section through an end cap of the member of Figure 1;

85 Figure 3 shows a section through the spaceframe member of Figure 1;

90 Figure 4 shows a plan view of a double-layer grid spaceframe;

95 Figure 5 shows a section on the line V-V of Figure 4; and

100 Figure 6 shows a perspective view of a connection of spaceframe members at a node of the spaceframe illustrated in Figures 4 and 5.

105 A spaceframe as illustrated in Figures 4 to 6 is made up of a plurality of tubular members 2 and nodes 4.

110 Each tubular member 2 comprises a hollow tube 6 with an end cap 8 joined to the tube 6 at each end. The end caps 8 are designed to co-operate with connecting plates 10 and 12 at the nodes 4, as illustrated in Figure 6.

115 The method of construction of a tubular member 2 will now be described in more detail with reference to Figures 1 to 3 of the drawings. The tube for each member consists of a length (e.g. 0.5 metres to 1.0 metres), of, for example, 25mm diameter pultruded G.R.P. tube. End caps 8 are mounted to each end of this tube and are designed to transfer load from the tube to the nodes. The end caps 8 are made from injection moulded fibre-filled thermoplastics polymer material. A suitable material is glass fibre-filled Nylon 66. It will be appreciated that other thermoplastics materials with or without fibre reinforcement are

suitable for this purpose. It would also be possible to use aluminium end caps.

The end cap 8 which is illustrated in more detail in Figures 2 and 3 has inner and outer annular walls 14, 16 which define an axially extending annular gap 18 which is closed off by an end 20 of the end cap.

Threads 22, 24 are formed in the facing surfaces of the inner and outer walls 14, 16. It is also possible to provide threads in one only of the inner or outer walls.

These threads 22, 24 are helical and substantially of the same pitch in order that the end cap can readily be moulded. The central portion 26 of the end cap is hollow. There are five pairs of tapered nibs 28 on the external face of the end cap. These nibs 28 co-operate with slots in the connecting plates 10, 12 of the node as will be described in more detail later.

The end cap is preferably formed by injection moulding in one-piece.

In order to connect the tubes to the end cap, a measured quantity of epoxy resin adhesive, for example Ciba Gigy AY 105/HY 956 (or similar), is injected into the gap 18 and the end portion of the tube 6 is pushed into the gap until it reaches the end 20. This forces the adhesive to run around the threads 22, 24 on either side of the tube where it sets. The presence of the threads controls the glue line thickness. Moreover, as the adhesive must run round the threads before it can reach the outside of the end cap, the escape of adhesive provides an indication of the fact that adhesive must have run around the entire threads 22, 24. The adhesive forms a mechanical bond with the end cap because of the grooved surface provided by the threads 22, 24. It is necessary that the adhesive should form a mechanical bond with the end cap as only a poor chemical bond is formed between the adhesive and the thermoplastics of the end cap. Preferably, the end of the tube 6 is lightly roughened before it is inserted into the end cap 8. This ensures the very good chemical bond to the glass fibres within the tube.

In order to increase the loading on a spaceframe structure, the most highly stressed tubular members may have tubes 6 which are made of carbon fibre reinforced polymer.

Whilst hollow tubular members 6 have been envisaged these members could also be solid in which case the end cap 8 would not have the externally threaded inner wall 14. Where the end caps 8 are aluminium, this type of construction with no inner wall 14 is also preferred.

Figures 4 and 5 show a typical double-layer grid spaceframe construction with "square-on-square" member configuration. The construction is made up of a number of tubular members as described connected at nodes 30 by connectors which are not shown in Figures 4 and 5 but one of which is illustrated in Figure 6. Each node 30 which is not at the edge of the spaceframe connects eight tubular members. Four of these tubular members extend at right angles to one another in a horizontal plane, and the remaining four are either downwardly or upwardly inclined at an angle of, for example, 45°. The same node can therefore be employed at all points in the body of the spaceframe, whether or not these are in the top or bottom layer. Such a spaceframe is suitable for use as

a suspended ceiling or as an exhibition stand roof. It will be appreciated, also, that there are a great number of other possible applications.

The node illustrated in detail in Figure 6 comprises co-operable top and bottom connecting plates 10, 12. The connecting plates are injection moulded from glass fibre-filled thermoplastics material, for example Nylon 66 for compatibility with the end caps. Each connecting plate has an oriented recess 32 for receiving half of the end cap 8 of each of the tubular members to be connected. Each of the recesses 32 is provided with five tapered slots into which the nibs 28 tightly fit. In this way, the eight tubular members are retained in one of the connecting plates during assembly of the node. Assembly is completed by positioning the other connecting plate over the tubular members so that the slots 34 in the recesses 32 of that plate engage the other nibs 28 on the opposite side of the end caps of the connecting members. The top and bottom connecting plates are secured together by means of, for example, a 10mm steel nut and bolt. The thickness of the connecting plates will vary to take account of the anticipated stress distribution - the plates will be at their thickest (probably 5mm) around the slots 34 and the central bolt holes where the greatest stress concentrations will occur.

It will be appreciated that the method of structurally connecting a thermoplastics polymer or aluminium element to a thermosetting polymer element which has been described above in relation to the attachment of a thermoplastics end cap 8 to a thermosetting tubular member 6, has possible wider applications.

In particular it is envisaged that elements of other shapes may be connected. For example, a laminar member may be inserted into a gap in a member to which it is to be connected. In this case each surface of the thermoplastics or aluminium member which co-operates with a surface of the laminar member in the gap will be grooved. In this way adhesive in the gap will form a mechanical bond with the thermoplastics member due to the presence of the grooves in that member's surface.

#### CLAIMS

1. A structural connection comprising two elements, one of which comprises a first polymer material and the other of which comprises thermoplastics material or aluminium, a recess in one element which accommodates an end portion of the other element, the thermoplastics or aluminium one of each pair of co-operating surfaces of said elements in said recess being provided with a grooved surface, and adhesive substantially filling the space between each pair of co-operating surfaces which adhesive chemically bonds to the first polymer material.

2. A structural connection wherein the first polymer is a thermosetting polymer.

3. A structural connection as claimed in claim 1 or 2, wherein one of said elements is a tube and said recess is in the form of an axially-extending annular recess in the other element.

4. A structural connection as claimed in claim 3, wherein said grooved surface comprises threaded inner and/or outer wall surfaces defining said recess.

5. A structural connection as claimed in claim 4, wherein the threads are helical and, where both

surfaces are threaded, the threads are of substantially the same pitch.

6. A structural connection as claimed in claim 4 or 5, wherein said tube is a fibre reinforced thermosetting polymer tube.

7. A structural connection as claimed in claim 6, wherein said end portion of the tube is roughened to enable the adhesive to form a chemical bond with fibres in the material thereof.

8. A structural connection as claimed in any one of claims 2 to 5, wherein the other element comprises a thermoplastic injection moulding.

9. A construction member for use in assembling a spaceframe comprising a hollow tubular member and a pair of end caps secured to each end of said tubular member by means of a structural connection as claimed in any one of the preceding claims.

10. A construction member as claimed in claim 9, wherein each of the end caps is provided with a plurality of laterally extending nibs.

11. A spaceframe constructed from a plurality of members as claimed in claim 10, said members being connected at nodes of the spaceframe by means of co-operating top and bottom connecting plates which engage said nibs and clamp the end caps of the members in a desired position relative to one another.

12. A method of forming a structural connection between an end of a cylindrical member and a closed-ended member having an internally threaded annular wall defining a recess having substantially the same diameter as the cylindrical member, comprising the steps of introducing adhesive into said recess and pushing said cylindrical member into the recess until it reaches the closed end, thereby forcing adhesive to run around the thread to substantially completely fill the space between the wall and the cylindrical member.

13. A method as claimed in claim 12, wherein the cylindrical member is a hollow tube and the closed-ended member has a further externally threaded annular wall which with said internally threaded wall defines an annular gap of a width substantially equal to the wall thickness of the tube.

14. A structural connection substantially as herein described with reference to Figures 1 to 3 of the accompanying drawings.

15. A method of forming a structural connection substantially as herein described with reference to Figures 1 to 3 of the accompanying drawings.

16. A kit of parts for forming a spaceframe structure substantially as herein described with reference to the accompanying drawings.

17. A spaceframe structure substantially as herein described with reference to the accompanying drawings.